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# SOIL CHEMISTRY RELATIONSHIPS OF THE TECATE CYPRESS IN THE SANTA ANA MOUNTAINS, CALIFORNIA

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The Tecate cypress, *Cupressus guadalupensis* Wats. subsp. *forbesii* (Jeps.) Beauchamp ex Thorne (Thorne 1978), is a stately conifer greatly restricted in its distribution. In the Santa Ana Mountains it is limited primarily to the Pacific Slope between Gypsum and Coal canyons and Sierra Peak in Orange County (Wolf 1948; Armstrong 1966; Lathrop and Thorne 1978) (Fig. 1). Outside of the Santa Ana Mountains, the significant groves are located essentially only in: El Canon de Pintos, Rancho El Cipres, and Rancho Rinconada in Baja California; on Tecate, Otay, and Guatay Mountains in San Diego County, California (Epling and Robinson 1940; Wolf 1948; Armstrong 1966). This distribution is rather unusual for a woodland tree, which normally would be found throughout a range where its ecological requirements are met.

The purpose of this study was to attempt to determine if soil is an influencing factor in the distribution of the Tecate cypress. The study was approached by comparing soil characteristics of the Tecate cypress groves in the Santa Ana Mountains with soils from neighboring communities and other Tecate cypress groves in California (Figs. 1 and 2).

Among the trees of the southwestern United States are found several examples of edaphic restrictions, where the trees are confined to soils or substrates having particular characteristics. Billings (1950) found that in the western Great Basin *Pinus ponderosa* Laws. and *P. jeffreyi* Grev. & Balf. in A. Murr. are limited to chemically altered andesite soils that are lacking in available phosporus and nitrogen. In the Santa Ana Mountains, the Knobcone pine (*Pinus attenuata* Lemmon) is confined in its range to hydrothermally modified serpentinite soil within a radius of 1.6 km of Pleasants Peak (Vogl 1973, 1976). McMillan (1956) has listed several species of *Cupressus* limited to either serpentine or acidic soils. Among these species is *C. pygmaea* Sarg., which is limited to some of the most acidic soils (pH 3.5–4.0) in California.

Although the soils of the Tecate cypress in the Santa Ana Mountains have not been previously studied, several clues pointing to possible soil factors are found in the literature. Wolf (1948) noted that all the groves are located in coarse, rocky, and sterile soils with little annual growth with which to compete. Armstrong (1966) states that chaparral is sparse and stunted throughout the Sierra Peak and Otay Mountain groves with all groves having

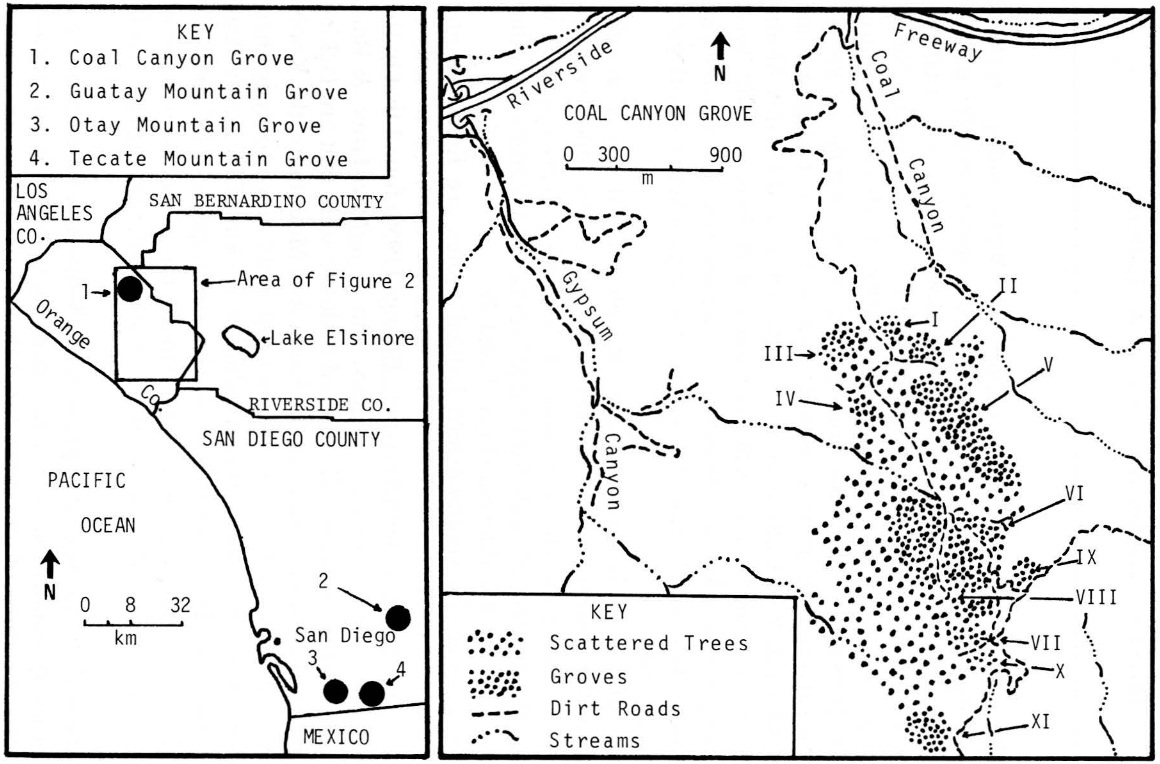


Fig. 1. Map comparing location of the Santa Ana Mountain main study area (Coal Canyon) with the San Diego County Tecate cypress groves. The Coal Canyon area is enlarged to the right showing the soil sampling sites as indicated by Roman numerals.

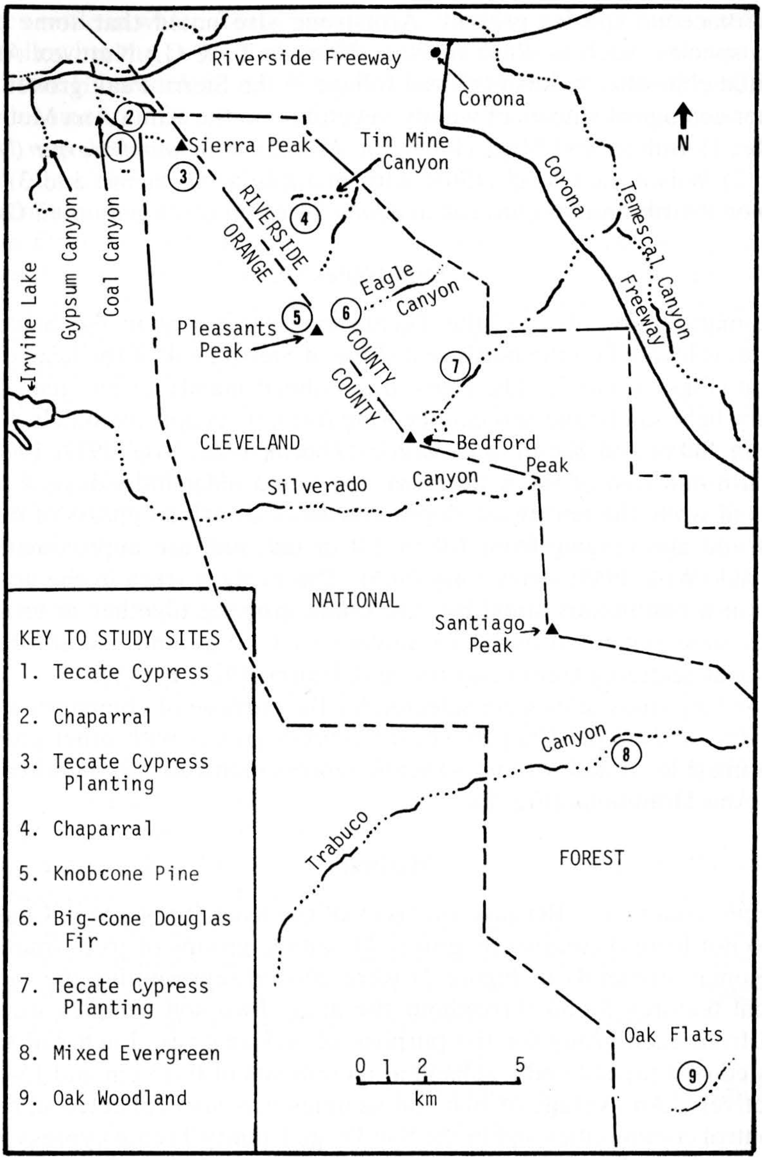


Fig. 2. Map showing location of the Tecate cypress study site in Coal Canyon and adjacent comparison study sites in the Santa Ana Mountains.

few herbaceous species present. Armstrong also noted that some broad-leaved species, such as *Rhus laurina* (Nutt. in T. & G.) Nutt. ex Abrams exhibited chlorotic, reddish-colored foliage in the Sierra Peak grove.

Other ecological studies of woody vegetation in the Santa Ana Mountains include: 1) Bolton and Vogl (1969) for *Pseudotsuga macrocarpa* (Vasey) Mayr; 2) Wilson and Vogl (1965) with manzanita chaparral; and 3) Snow (1972) on distribution of *Quercus agrifolia* Nee and *Q. engelmannii* Greene.

## Study Sites

The main study site was the Tecate cypress groves in the Santa Ana Mountains located on the northwest slope of Sierra Peak at the head of Coal Canyon (Figs. 1 and 2). The trees are confined mainly to an area of sedimentary light sandstone and clay-bearing formations approximately 1.6 $km^2$ between 400 m and 800 m in elevation (Thorne 1976; Vogl 1973, 1976). To the south and east of the main grove are found older individuals 4.5 m to 7.6 m tall while the northwest slopes consist of dwarfed cypress of uniform height and age ranging from 1.0 to 2.0 m tall, and are approximately 30 years old (Wolf 1948; Armstrong 1966). The cypress trees in the grove do not form a continuous stand but are found growing together in groups of various sizes separated from one another by bare ground and shrubs with occasional scattered trees (Lathrop and Thorne 1978, Fig. 9).

Secondary study sites were selected for the purpose of comparing the soil chemistry of the Coal Canyon Tecate cypress groves with other groves in California (Fig. 1) and with non-Tecate cypress (control) communities in the Santa Ana Mountains (Fig. 2).

## Methods

*Sample selection.*—Because the trees of the main study site in Coal Canyon do not form a continuous grove, 11 sample groups of trees (numbered with Roman numerals in Figure 1) were chosen representing the range of physical features found throughout the area. Two soil samples were collected from each group for the purpose of soil analysis. Each soil sample consisted of a topsoil and a subsoil at increments of 0–15 cm and 15–30 cm respectively. An average of two soil samples was also collected in each of the control communities and in the San Diego County Tecate cypress groves for comparison. Two Tecate cypress plantings, consisting of approximately 8 trees per site, were also sampled at Bedford Road and Sierra Peak Road in the Santa Ana Mountains (Fig. 2, nos. 3 and 7).

*Soil analyses.*—Comprehensive methods of soil analyses are outlined in Black (1965). Soils were dried in a constant temperature cabinet at 25 C, passed through a 2-mm sieve, and analyzed for texture by the Bouyoucos method (Bouyoucos 1926) which is based on the rate different sized soil particles settle in water. The screened soil was also used to make a saturated paste following the procedure outlined in the United States Department of Agriculture Handbook no. 60 (United States Salinity Laboratory Staff 1954). From the amount of water added to form the saturated paste, the saturation percent was determined. This paste was also used for determining pH with the aid of a Corning model 7 pH meter.

Electrical conductivity was determined on the soil extract obtained by vacuum filtration from the saturated soil paste with a Yellow Springs Instrument Co. model 31 Conductivity Bridge. Salts in parts per million (ppm) were determined by multiplying the electrical conductivity in micromilliohoms per centimeter (E.C. mmhos/cm) by 640. The saturation paste extract was saved for further testing.

*Soil testing.*—The soil samples were assessed for the following nutrients:

1. Nitrogen (N). The MicroKjeldahl Method, modified to include nitrates, was used to determine the amount of nitrogen in each soil sample in parts per million (Bremner 1960). Organic and nitrate nitrogen was converted to ammonium sulfate and the ammonium distilled into boric acid and titrated with standard sulfuric acid using brom cresol green-methyl red as indicator. Blanks were run and parts per million nitrogen determined using the following equation:

$$\text{ppm N} = \frac{[(\text{ml } H_2SO_4) - (\text{blank})](\text{normality of acid})(14)(100)}{\text{weight of sample in mg}}$$

2. Phosphorus (P). Top and subsoils for each Sierra Peak grove were equally mixed by weight to form one composite topsoil and subsoil per grove. Each top and subsoil sample underwent digestion by perchloric acid (Shelton and Harper 1941) for phosphorus determination using the Bausch and Lomb Spectronic 20 at 660 m$\mu$. The resulting perchloric acid extracts were reacted with molybdate to form phosphomolybdate. A blue-colored complex forms which is proportional to the amount of phosphate present. Ten phosphorous standards from 0.1 to 1.0 ppm were also run and a straight-line relationship was found by using the method of least squares:

$$X = \frac{y - b_0}{b_1}$$

$y$ = absorbance
$x$ = phosphorous in parts per million
$b_0$ = intercept
$b_1$ = slope

3. Potassium (K), Calcium (Ca) and Magnesium (Mg). The soil extract used in the soil analysis section was tested for these elements using a Varian Techtron Atomic Absorption Spectrophotometer Model AA6. The instrument was used according to instructions in the Varian Techtron manual (Varian Techron 1972) and aliquots of the extract were diluted to bring the concentration of the element within optimum working range. High and low

standards for each element were run and a straight-line relationship found by the method of least squares. A suppressant, strontium at 550 ppm, was added to all samples, standards, and to the blank. Results were recorded in parts per million of the saturated soil extract.

4. Iron (Fe), Manganese (Mn), Copper (Cu), and Zinc (Zn). The soil extracts were tested for these elements by the atomic absorption method without dilution or addition of a suppressant. The machine was used according to the manual for each element and a high and low standard was run for each. Using the straight equation by the method of least squares, we determined the parts per million of each element in the saturated soil extracts.

## Results

Results of the soil analyses and soil testing for the Coal Canyon main study site and the other Tecate cypress sites, Gautay, Otay, and Tecate Mountains, are summarized in Table 1. Results for the non-Tecate cypress communities are summarized in Table 2.

Results from the soil texture analyses indicate that the Tecate cypress grows on a variety of soil types ranging from sandy loam to clay. The Guatay and Otay Mountain sites had higher percentage clay than Coal Canyon, with the Tecate Mountain site having the least clay. Pequegnat (1951) reported that the Tecate cypress of Sierra Peak tends to grow in rich clay soils. Results of the texture analyses are recorded as percent clay.

The mean saturation percent for the Coal Canyon site top and subsoils was 26.6 and 25.1 respectively. Saturation percent, which is related to the water-holding capacity of the soil, was generally lower in the Coal Canyon site than in the other Santa Ana Mountain woodland and chaparral soils tested. This indicates a poorer water-retaining capacity for the Coal Canyon Tecate cypress soils. The Coal Canyon study site had only half the water-retaining capacity of the mixed evergreen woodland site which had a saturation percent of 55.7 for topsoils and 40.5 for subsoils. The San Diego County Tecate cypress groves also had comparatively higher saturation percent values than the Coal Canyon study site, while the two Tecate cypress plantings had values of approximately the same as the Coal Canyon sample.

A range of values for evaluating soil analyses and soil tests is given in Table 3. Electrical conductivity showed very little salt present at the Coal Canyon site except for groups II and IV which are both located on mining skrees. Group IV fell within a range considered restrictive to salt-sensitive plants (Table 3). All other sites tested fell within a range in which no salinity problem should be expected.

The pH values for the main study site ranged from a low of 4.2 to a high of 6.5 with a mean of 5.5 for topsoils and 5.4 for subsoils. Chaparral soils had higher values ranging from 5.7 to 7.1 with a mean of 6.2. The other non-

Table 1. Mean values (±1 sd) of soil analyses from 11 study sites in the Coal Canyon Tecate cypress groves. Average values (N = 2) of soil analyses from three other disjunct Tecate cypress groves are included for comparison. The first and second values listed are taken from the 0–15-cm and 16–30-cm soil-depth increments respectively.

| | Tecate cypress sites | | | |
|---|---|---|---|---|
| Soil chemistry | Coal Canyon | Guatay Mountain | Otay Mountain | Tecate Mountain |
| Saturation % | 26.6 ± 4.3 | 39.4 | 34.3 | 46.5 |
| | 25.1 ± 4.8 | 35.5 | 27.4 | 34.2 |
| Clay % | 28.1 ± 10.0 | 52.4 | 35.8 | 17.2 |
| | 30.8 ± 8.1 | 47.4 | 40.7 | 25.2 |
| E. C. nmhos/cm | 0.59 ± 0.9 | 0.39 | 0.36 | 0.43 |
| | 0.52 ± 0.8 | 0.15 | 0.19 | 0.35 |
| Salts ppm | 205.2 ± 14.3 | 251.0 | 228.0 | 273.2 |
| | 123.9 ± 35.5 | 97.9 | 121.6 | 227.3 |
| pH | 5.5 ± 0.5 | 6.1 | 6.3 | 5.7 |
| | 5.4 ± 0.6 | 6.1 | 6.0 | 5.6 |
| N ppm | 0.71 ± 0.4 | 0.48 | 1.98 | 2.66 |
| | 0.46 ± 0.3 | 0.76 | 0.69 | 0.7 |
| P ppm | 21.8 ± 17.0 | 1.68 | 9.21 | 33.76 |
| | 17.6 ± 11.6 | 1.68 | 4.94 | 19.95 |
| K ppm | 6.4 ± 5.5 | 3.95 | 11.83 | 3.95 |
| | 3.6 ± 2.8 | 2.21 | 3.2 | 2.21 |
| Ca ppm | 27.2 ± 20.1 | 38.5 | 25.95 | 35.54 |
| | 21.6 ± 19.5 | 9.33 | 7.5 | 9.27 |
| Mg ppm | 9.5 ± 11.9 | 18.4 | 9.76 | 18.38 |
| | 9.9 ± 11.8 | 4.7 | 2.96 | 4.66 |
| Fe ppm | 1.3 ± 1.8 | 0.89 | 0.83 | 0.89 |
| | 1.2 ± 2.3 | 0.89 | 1.48 | 0.89 |
| Mn ppm | 1.8 ± 1.2 | 0.31 | 1.66 | 0.31 |
| | 1.1 ± 1.0 | 0.1 | 0.21 | 0.1 |
| Cu ppm | 0.03 ± 0.03 | 0.06 | 0.04 | 0.06 |
| | 0.04 ± 0.05 | 0.01 | 0.04 | 0.01 |
| Zn ppm | 1.2 ± 1.0 | 0.42 | 0.34 | 0.42 |
| | 1.1 ± 1.3 | 0.45 | 0.34 | 0.45 |

Tecate cypress sites had values that tended to fall in between the chaparral and the Tecate cypress soils in Coal Canyon. The Bedford Road planting is in an area of mixed chaparral and its pH of 7.4 reflects that of the surrounding soil, more so than that of Tecate cypress soils.

The nitrogen test resulted in values so small that few plants should be able to grow in any of the soils tested! After we checked technique and

Table 2. Average values (N = 2) of soil analyses of six control sites outside the Tecate cypress groves for comparison with Table 1. Location and community type of the numbered sites are shown in Fig. 2.

| | Control sites | | | | | |
|---|---|---|---|---|---|---|
| Soil chemistry | 2 | 4 | 5 | 6 | 8 | 9 |
| Saturation % | 36.5 | 37.5 | 34.8 | 49.0 | 55.7 | 27.6 |
| | 32.3 | 32.9 | 30.7 | 28.6 | 40.5 | 26.6 |
| Clay % | 21.2 | 24.2 | 33.6 | 30.2 | 26.2 | 34.3 |
| | 20.3 | 24.9 | 35.6 | 42.2 | 27.2 | 32.3 |
| E.C. mmhos/cm | 0.46 | 0.26 | 0.45 | 0.44 | 0.84 | 0.64 |
| | 0.27 | 0.24 | 0.72 | 0.31 | 0.68 | 0.45 |
| Salts ppm | 445.6 | 248.7 | 287.9 | 279.5 | 538.2 | 407.8 |
| | 171.6 | 154.0 | 461.2 | 198.8 | 438.5 | 290.8 |
| pH | 6.2 | 6.3 | 5.6 | 5.8 | 6.4 | 5.8 |
| | 6.5 | 6.4 | 6.1 | 5.8 | 6.5 | 5.8 |
| N ppm | 1.55 | 1.11 | 1.22 | 2.03 | 4.68 | 0.44 |
| | 0.68 | 0.8 | 0.83 | 1.02 | 3.82 | 0.6 |
| P ppm | 7.22 | 5.4 | 23.24 | 76.73 | 85.94 | 56.31 |
| | 5.15 | 5.15 | 24.01 | 61.38 | 79.80 | 61.38 |
| K ppm | 2.06 | 1.26 | 13.58 | 16.04 | 16.85 | 17.15 |
| | 0.71 | 0.49 | 7.58 | 9.06 | 12.89 | 11.24 |
| Ca ppm | 67.43 | 14.62 | 33.02 | 46.32 | 115.94 | 68.33 |
| | 36.21 | 18.27 | 99.11 | 26.51 | 95.0 | 54.38 |
| Mg ppm | 12.52 | 13.39 | 12.74 | 16.7 | 23.32 | 14.6 |
| | 4.85 | 14.4 | 14.38 | 13.0 | 21.2 | 10.95 |
| Fe ppm | 0.31 | 0.18 | 1.58 | 1.41 | 0.32 | 0.08 |
| | 0.74 | 0.17 | 1.82 | 0.76 | 0.27 | 0.06 |
| Mn ppm | 0.67 | 0.21 | 4.3 | 2.92 | 0.44 | 0.76 |
| | 0.12 | 0.49 | 1.84 | 0.86 | 0.43 | 0.46 |
| Cu ppm | 0.04 | 0.04 | 0.03 | 0.01 | 0.12 | 0.07 |
| | 0.01 | 0.01 | 0.03 | 0.08 | 0.1 | 0.06 |
| Zn ppm | 0.3 | 0.2 | 0.79 | 0.76 | 0.58 | 0.7 |
| | 0.28 | 0.18 | 1.23 | 0.46 | 0.58 | 0.48 |

methods, selected soils, both air dried and oven dried, were again tested using fresh reagents and normal solutions. There was no significant change in values, and no source of error could be found. Mixed evergreen soil had the most nitrogen of all soils tested, ranging from 2.04 to 6.13 ppm. The other non-Tecate cypress soils had average values falling between 1.0 and 2.0 ppm, while the main study site had a mean of 0.71 ppm for topsoils and 0.46 for subsoils.

Table 3. Normal range of values expected from soil analyses and soil test for evaluating significance of constituents found in soils (Chapman and Pratt 1961).

| Analyses and tests | Range of values | |
|---|---|---|
| Electrical Conductivity (E.C.) | less than 2.0 mmhos | no salinity problem |
| | 2.0–4.0 mmhos | restricts growth of very salt-sensitive plants |
| | 4.0–8.0 mmhos | restricts growth of many plants |
| | 8.0–16.0 mmhos | restricts all but salt-tolerant plants |
| | more than 16.0 mmhos | only a few salt-tolerant plants can grow |
| Nitrogen (N) | 1.0–50 ppm | low in nitrogen |
| | 50–300 ppm | usual range |
| Phosphorus (P) | 30–300 ppm | |
| Potassium (K) | 1–25 ppm | |
| Calcium (Ca) | 2–200 ppm | |
| Magnesium (Mg) | 1–120 ppm | |
| Iron (Fe) | a fraction to several parts per million | |
| Manganese (Mn) | a fraction to a few parts per million | |
| Copper (Cu) | less than 1 ppm | |
| Zinc (Zn) | less than 1 ppm | |

Results of the phosphorus test showed that the mixed evergreen, Big-cone Douglas fir, and oak woodlands sites had the highest values, but were well within normal range. The Knobcone pine site and most of the Tecate cypress groves followed with slightly deficient values while the chaparral sites and the Tecate cypress grove on Guatay Mountain had the least amount of phosphorus of the soils tested.

Potassium values were in the normal range for all but three subsoils and tended to fall into the same order mentioned in the phosphorus test, with the three control woodlands having the highest. Potassium values for chaparral sites were the lowest and values for the Knobcone pine and Tecate cypress sites were in between.

The samples from groups II and IV, located on mine skrees in the Sierra Peak study site, had the highest concentrations of calcium and magnesium of all the soils tested. Values for all the other soils tested fell within the normal range, with mixed conifer, Big-cone Douglas fir, oak woodlands, and Knobcone pine sites generally higher than the Tecate cypress groves, the tecate plantings, and the chaparral community.

Iron, manganese, copper, and zinc are usually found in only small amounts in soils. The soils tested showed average amounts of these elements, except for the Coal Canyon group IV (mine skree) which had the highest concentration of manganese, copper, and zinc.

## Conclusions

Two factors appear to distinguish the soils of the Coal Canyon Tecate cypress grove from the control soils in the Santa Ana Mountains:

1. Results indicate that the Tecate cypress soils of the Coal Canyon site are definitely more acidic than the surrounding chaparral soils. Using the student *t*-test with a 95% confidence interval, we found that the chaparral and mixed conifer soils are significantly different from those of the Coal Canyon Tecate cypress.

Soil pH affects the solubility and availability of many elements. Values of pH 5.0 or less may cause elements such as calcium, magnesium, phosphorus, molybdenum, or boron to become unavailable while iron, zinc, copper, and manganese become more available, even toxic, due to increased solubility.

2. In terms of nutrients, the Tecate cypress soils are significantly different from the soils of Big-cone Douglas fir, Knobcone pine, mixed evergreen, and oak woodlands in that they have about half the amounts of phosphorus, potassium, and magnesium.

Between the three San Diego groves and the Coal Canyon grove, the following similarities and differences were noted: 1) The soils from Guatay and Otay Mountains have more clay in them and are less acidic than the Coal Canyon site; 2) Tecate Mountain has less clay than Coal Canyon and its pH is virtually the same, falling within the 95% confidence interval of the student *t*-test; and, 3) Values of the other chemical tests are not significantly different between groves. Comparison of the Tecate cypress planting of Sierra Peak Road and Bedford Road with their controls indicates that these two plantings are growing on essentially the same type of soil as the surrounding chaparral. It might be conceivable that, when in competition with chaparral plants, the Tecate cypress are apparently at a disadvantage because they are intolerant to shade and are slower growing. After a fire on typical chaparral soils, the slower-growing cypress seedlings may be unable to compete with the rapidly growing chaparral and, when shaded, the mortality rate of seedlings is very high (Armstrong 1966). In acidic soils, however, the chaparral plants are either unable to obtain the nutrients they need or the nutrients are in toxic concentrations. Under these conditions the Tecate cypress may be better adapted for nutrient uptake, and are able to compete and reproduce.

Thus it appears that the Tecate cypress may be limited to acidic soils that are nutrient poor, thereby lacking the competition from chaparral found on normal soils. This may be a factor in their limited distribution in the Santa Ana Mountains and other southern California sites.

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